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CHEMICAL CONTROL OF THE GARDEN CENTIPEDE, SCUTIGERELLA IMMACULATA[1]

A. E. MICHELBACHER[2]

Chemical treatment is often recommended for the control of soil pests, but the effectiveness of the chemicals is not always stated. This is particularly true in the case of the garden centipede, *Scutigerella immaculata* (Newport). With this in mind considerable work was done during 1931 to determine the effectiveness of various fumigants in the control of this pest. The materials used were carbon disulfide, carbon disulfide emulsion, paradichlorobenzene, calcium cyanide, naphthalene, potassium xanthate mixed with sulfur, hydrated lime mixed with sulfur, chloropicrin, carbon tetrachloride, and lead arsenate.

PREVIOUS WORK

Up to the present time most of the control work against the garden centipede has been done in greenhouses, although attempts at controlling the pest under field conditions have been made. Methods used are soil fumigation, steam sterilization, poison baits, and installation of raised benches in greenhouses.

The method most generally agreed upon as giving best results under greenhouse conditions is the installation of raised benches. McDaniel(8) [3] states that the cheapest and most satisfactory method of controlling the garden centipede consists in breaking the contact between the soil and subsoil. This, he further states, can most effectively be done by placing a matched board shield about 10 or 12 inches beneath the soil, or by installing benches with an air space between the bottom of the bench and the underlying soil. Compton(1) states that the "most effective permanent control is obtained by raising the benches and supplying clean soil." Filinger(4, 5) reports that where the installation of raised benches is practical it will solve the symphylid problem. Others who have recommended raised benches as an effective means of control are Herrick,(6) Wallace *et al.*,(15) and Riley.(12)

[1] Received for publication September 13, 1932.

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[3] Superscript numbers in parentheses refer to "Literature Cited" at the back of bulletin.

There is some evidence that the installation of raised benches is not always sufficient to prevent serious centipede damage. In Illinois[7] the pest is reported to have caused serious damage to chrysanthemums, roses, and tomatoes. However, this trouble was corrected by removing the soil, thoroughly cleaning the raised benches, and supplying new soil.

Steam treatment (steam sterilization)[4] is another means often used in the control of the symphylid. According to McDaniel[8] "ordinary soil sterilization will kill the individuals near the surface, but will not affect those in the subsoil." Compton[1] found that steam treatment would kill all the symphylids in the upper part of the soil, but that in the case of ground beds, treatment must include the walks to be effective. Even then, he states, some of the symphylids and their eggs in the subsoil will survive, necessitating yearly treatments if they are to be kept under control. In his work in Ohio, Filinger[5] found that the buried-tile method of steam treatment was the only one that proved successful, and even that was effective only during the fall or winter when the centipedes are occupying the soil strata above the tiles. Further, the paths should be sterilized if possible. Thomas,[14] carrying on investigations in Pennsylvania, found steam treatment not wholly satisfactory even though the soil temperature rose above 160° F. He observed that many of the symphylids escaped by entering cracks in the concrete walls of the bed. Riley[12] in Indiana has observed that many centipedes are killed in the usual steam treatment as practiced by growers for the control of plant pests, such as lettuce drop and root nematodes, but that a sufficient number escape to maintain the infestation from year to year.

Walton[16] working at Long Ashton, Bristol, England, reports attempts to control the centipede in infested areas by setting out tomato plants with roots and soil enclosed in grease-paper bags. The plants continued to grow until the paper decayed. The use of this method enabled the plants to gain size and hence greater resistance before being subjected to attack by the pest.

There has been much conflicting evidence obtained where chemicals have been used in control of the garden centipede. McDaniel[8] reports that the use of chemicals in infested soil where crops are growing has not proved satisfactory to date. Compton[1] states that in Illinois a large number of chemicals have been tried, but none of the treatments so far devised is satisfactory under the conditions maintained in greenhouses devoted to the production of sweet peas and other flowers.

[4] Although the term "steam sterilization" is commonly applied to this method, complete eradication of life is seldom accomplished.

Considerable experimental work has been done with paradichlorobenzene. Feytaud,[3] carrying on work in France, reports his work with this material as not sufficiently conclusive to be recommended on a large scale. Wymore,[17] working in California, found paradichlorobenzene in several cases to be very effective, but under field conditions it did not prove so promising. This may have been due to the fact that the soil was not packed sufficiently at the time the material was applied. Also, the soil temperature may have been too low. According to the investigations carried on by Filinger[5] in Ohio, this material gave good results if applied in the summer or early fall when the symphylids are still in the subsoil. The surface soil is first removed and the paradichlorobenzene scattered over the subsoil at the rate of 1 pound to 100 square feet. After this the surface soil is again replaced. Essig,[2] working in California, reports that paradichlorobenzene proved unsatisfactory on the whole, probably because of the very porous condition of the peaty soils in which the experiments were made. In Oregon[10] paradichlorobenzene is reported as having a repellent effect and as killing a few of the symphylids. In Pennsylvania[14] this material is said to be ineffective in killing the centipede but has a repellent effect upon it. Riley,[12] carrying on investigations in Indiana, used paradichlorobenzene as a barrier between the surface soil and the subsoil. The work was done in the fall when the centipedes were in the subsoil and for a few weeks after treatment none could be found in the surface soil which was planted to lettuce. However, the centipedes soon began to work through the barrier, and within a year's time large numbers could be found.

Filinger[5] has used calcium cyanide against the garden centipede with success. He states that the material used at the rate of 1 pound to 75 square feet is effective when scattered over the subsoil and covered quickly. Wymore,[18] working with the same material under field conditions in California, found it to give only temporary relief. In Oregon[10] calcium cyanide is reported to have given practically no control.

Crude naphthalene has been used but has not proved to be of any value. Work in Pennsylvania[14] has shown naphthalene flakes to act as a repellent.

Herrick[6] has used carbon disulfide emulsion effectively against the centipede. A solution of miscible carbon disulfide was used at the rate of 1 gallon to 100 gallons of water for drenching the soil that had just been brought in from the fields and placed in the beds. He states that the dilute mixture used at the rate of 100 gallons for a bed 3 feet wide

and 160 feet long appeared to result in 100-per-cent mortality. Examination of the soil for centipedes was made about 12 hours after the bed had been treated, and Herrick remarks that probably some of the centipedes escaped, although the examination was thorough. Filinger[5] carried on some work with carbon disulfide emulsion, and his investigations showed that when it was used as a surface application it failed to control the pest. His stock mixture was prepared by dissolving 5 pounds of fish-oil soap in 3 gallons of water, to which 6 gallons of carbon disulfide were added, and the mixture emulsified. The heaviest application consisted of 3 quarts of the stock emulsion to 50 gallons of water, applying the dilute mixture at the rate of ½ gallon to each square foot of surface. After such treatment the plants grew vigorously for a while, but before the crop was mature centipedes came from the subsoil and destroyed the plants. Work in Oregon with carbon disulfide emulsion showed it to act as a repellent for a short time. Riley[12] used carbon disulfide emulsion against the centipede but reports it as being ineffective.

Filinger's[5] investigations in Ohio showed that carbon disulfide proved satisfactory in the control of the symphylid when used at the rate of 1 ounce to a square foot. He applied it by sprinkling over the subsoil at the time of the so-called "making up"[5] process. He also reports the material as being very effective when "drilled" on both sides of the plant rows at the rate of 4 pounds to 150 feet of row. For good results it should be drilled in about 4 inches from the base of the plants and about 2½ inches below the soil surface. Riley,[12] investigating in Indiana, has reported hand injections of carbon disulfide at the rate of 1 ounce to a square foot as giving desirable results. He[11, 12] also obtained good control when carbon disulfide was volatilized with steam and passed under pressure into ground benches which had previously been equipped with tiles for steam treatment. Sheaffer[13] gives the same recommendations as Riley.

It has been reported from Indiana[15] that creosote acts as a repellent to the centipede in ground benches, either applied as a light spray when spading or as a dressing, using sand soaked with creosote and turning the sand under.

In Oregon[9, 10] it was found that poisoned corn (corn soaked for 48 hours in bichloride of mercury, 1 pound to 600 gallons of water), caused the death of some centipedes, and that for several weeks after planting there were fewer centipedes in a treated area than in the check plot.

[5] In the "making-up" process the surface soil is removed to a depth of 6 to 8 inches, then a layer of manure is placed on the subsoil, and the surface soil is replaced on top of the manure.

It is also reported that most of the corn was eaten by the symphylids. In Pennsylvania[14] a poison bait consisting of bran and syrup mash containing sodium arsenite proved nonattractive to the centipedes. It is also reported that slices of potato covered with paris green were nonattractive.

Wymore,[17, 18] in California, has reported flooding as being very effective in the control of the garden centipede. His work in asparagus fields indicates that flooding to the depth of a foot or more for two or three weeks, during the winter when the plants are in a dormant condition, gives good results.

Many investigators are of the opinion that frequent cultivation is unfavorable to the centipede and that great care should be used to avoid transporting the organism into greenhouses. Sanitary practices and sterilization of soil before placing it in beds should be carried out where possible.

CONDITIONS UNDER WHICH EXPERIMENTAL WORK WAS CONDUCTED

A field infested with centipedes at Clarksburg, California, was divided into 39 plots by ditches which were approximately 30 inches deep. These ditches were partly filled with water, which served to isolate the plots. The water was supplied by a pump, and the height to which it might rise was regulated by an overflow drain at the lower end of the experimental area. The plots varied in size from 12 x 12 feet to 18 x 18 feet. Five plots so selected as to represent an average infestation were set aside as checks. Figure 1 shows the arrangement of the plots and the location of the checks.

There was some cracking and fissuring of the banks of the plots, and in order to compensate for this an extra heavy application of material was placed along the edge. In the case of the solid materials an amount equal to 10 grams per linear foot of perimeter was distributed in a furrow as close to the edges as possible. In the case of materials which were injected into the soil a double dose was given around the edge of the plots treated and in the case of carbon disulfide emulsion the banks were saturated. Cracking and fissuring of the banks permits the centipede, as well as other soil-infesting organisms, to escape treatment in spite of the fact that an extra amount of the fumigant is applied to the edge of the plot. To avoid this the edges of the banks should be well trimmed of all loose soil.

The soil in the experimental area is developed from a mineral sediment deposited by the Sacramento River. The surface soil to a depth

of 8 to 10 inches is a brown silty clay, finely granular in structure, with a high content of organic matter. The subsoil is a light-gray silty clay with rust-brown and dark-brown stains and is permeated with countless fine cavities left by decaying roots, which serve admirably as runways for the garden centipede.

At the time the chemicals were applied examinations showed that most of the centipedes were concentrated in the surface foot of soil, the majority being found in the first 9 inches. Molted skins were found at a

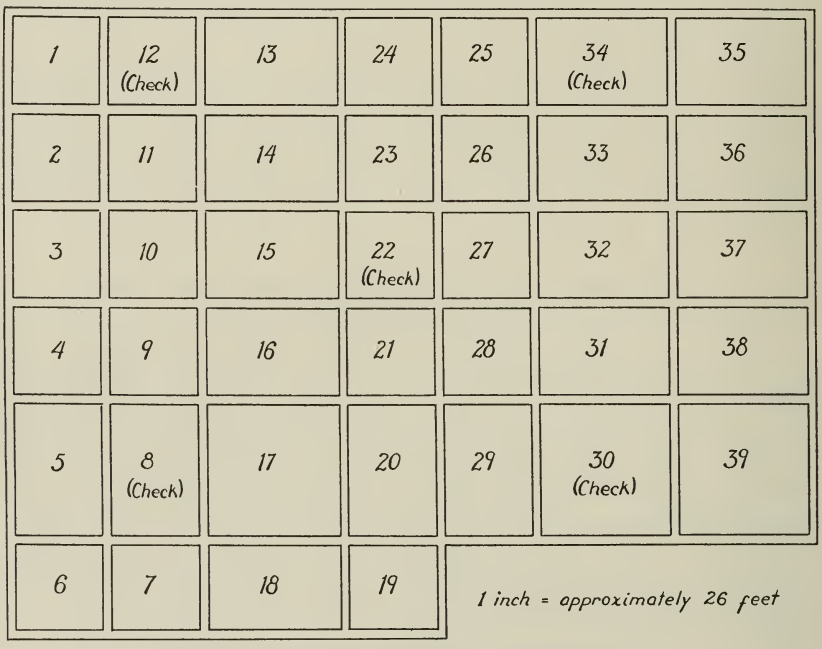

Fig. 1.—Arrangement of the experimental plots.

depth of over 2 feet, but they are very resistant to decomposition and had doubtless been shed in the fall before the plots were treated. At that season of the year the usual practice is to lower the water table by draining the ditches throughout the district, and as the soil starts to dry out the centipedes undoubtedly tend to move deeper into it. At the same time the plots were treated the water table, whose position varies during the year from 2 to 5 feet down, was within 2 to 3 feet of the ground surface. The surface soil at this time contained an optimum moisture content for plant growth.

Since the effectiveness of some of the chemicals used depends upon the temperature of the soil, records of soil temperature were taken for a period of approximately 2 months before and after treatment.

TABLE 1

Maximum and Minimum Temperatures for 3 and 10-inch Soil Depths on Days That Temperature Records Were Taken

Date (1931)	Temperature readings 3 inches deep		Temperature readings 10 inches deep	
	Maximum	Minimum	Maximum	Minimum
	°F	°F	°F	°F
June 24	96.0	69.0	75.5	73.5
June 25	96.0	70.5	77.5	75.5
June 30	92.0	69.0	76.5	75.0
July 1	94.0	71.5	78.0	76.0
July 9	94.0	71.0	80.0	77.5
July 14	86.0	67.5	79.0	76.5
July 15	85.0	67.0	77.0	75.0
July 16	93.0	70.0	79.0	76.5
July 21	96.0	74.0	82.0	79.5
July 23	98.0	76.0	82.5	80.5
July 28	82.0	68.5	79.5	77.0
July 29	88.0	69.0	79.0	76.5
July 30	93.0	69.0	79.0	77.0
August 6	81.0	63.0	76.0	64.0
August 13	81.0	62.5	77.5	74.5
August 14	83.5	66.5	76.0	74.0
August 20	85.5	68.0	77.0	75.0
August 21	94.5	69.5	78.0	76.0
August 25	96.5	72.0	82.5	79.5
August 26	97.5	72.0	82.0	78.5
September 2	82.5	67.0	75.5	72.0
September 3	80.0	68.5	74.0	72.0
September 10	81.0	63.0	72.5	70.0
September 11	82.5	63.0	73.0	70.0
September 15	74.0	62.5	70.0	68.0
September 16	78.5	64.0	71.0	69.0
September 24	79.0	60.0	70.0	67.0
September 29	73.5	59.0	69.0	66.0
October 7	73.0	59.0	68.0	66.0
October 8	72.5	59.5	67.5	65.5
October 9	73.5	60.5	68.0	65.5
October 16	77.0	60.0	68.0	65.5
October 21	66.0	59.5	64.5	63.0
October 30	72.0	53.0	63.0	60.5
November 4	71.5	53.0	63.0	60.5
November 18	55.0	43.0	55.0	52.0
December 2	50.5	47.0	49.0	48.5

In the center of the experimental area a Bristol's recording thermometer was installed. Soil temperatures were recorded for 3 and 10-inch soil levels. Table 1 shows the maximum and minimum temperatures for both levels on days that records were taken. The maximum temperatures were usually reached rather late in the afternoon (4 to 6 P. M.), while the minimum temperatures usually occurred between 5 and 8 A. M. The maximum and minimum temperatures for the 10-inch soil level lagged behind that of the 3-inch level.

METHODS OF APPLICATION

In treating the plots four methods of applying materials were used, namely, in furrows, broadcast and spaded under, injected or poured into holes in the soil, and mixed with water and poured over the soil.

Application in Furrows.—The nonliquid soil fumigants with the exception of naphthalene, lead arsenate, and the lime and sulfur mixture, were distributed in furrows 18 inches apart from center to center and approximately 6 inches deep. The furrows were made with a narrow shovel and were approximately 10 inches wide at the bottom. In applying the fumigants the material was scattered over this entire area. To insure even distribution of the chemicals the total amount necessary for any plot was first weighed out, then weighed into equal parts corresponding to the number of furrows for each plot. After the application of the fumigant the furrows were partly filled and the soil packed by walking back and forth on it. After this the furrows were completely filled and further packed.

The chemicals applied in the above manner were paradichlorobenzene, calcium cyanide, and a mixture of equal parts of potassium xanthate and sulfur. Paradichlorobenzene and calcium cyanide were applied at the rate of 300, 600, and 900 pounds to the acre, while the potassium-xanthate sulfur mixture was applied at the rate of 1,200 and 2,400 pounds per acre. All treatments were run in duplicate. The effectiveness of these chemicals is shown in table 2.

Broadcasting.—Chemicals applied by broadcasting were naphthalene, a mixture of equal parts of lime and sulfur, and lead arsenate. The exact amount of material needed for each of the plots was first weighed out, then to insure an even broadcast of the chemical over a plot, the material was again weighed into a number of equal smaller amounts. This greatly facilitated the even distribution of the materials over the plots. As soon as the chemical was broadcast it was spaded under. Naphthalene was applied at the rate of 1,200 pounds to an acre, lime sulfur mixture at the rate of 1,200 pounds per acre, and the lead arsenate at the rate of 300 pounds per acre. These treatments were also run in duplicate. Their effectiveness likewise is shown in table 2.

Injection.—Chemicals injected or poured into holes in the soil were carbon disulfide, carbon tetrachloride, and chloropicrin. The first two were poured into holes, while the last was injected into the soil with a mechanical soil injector. The apparatus used for applying the carbon disulfide and carbon tetrachloride consisted of a prod for making the

holes, and a funnel soldered to a length of pipe which could be inserted into the holes. The funnel was equipped with a small container which had a capacity of slightly more than 2 ounces. This small measuring device was suspended in the center of the funnel by means of a small cross rod so that it could be inverted to spill the measured liquid into the funnel, whence it passed down the tube into the soil. A dosage of 1.92 fluid ounces filled the container to the level of the supporting cross rod. A large teapot was used in filling the measuring device. In the case of the 0.96-ounce treatments the chemical was measured into a graduate and then poured directly into the funnel, whence it passed on into the soil. After the fumigants were applied the holes were filled and thoroughly tamped.

Carbon disulfide was applied at the rate of 1.92 fluid ounces per hole in 6-inch and 9-inch holes, and at 0.96 fluid ounce per hole in 6-inch holes; carbon tetrachloride was applied at the rate of 1.92 fluid ounces per hole in 9-inch holes, and chloropicrin at the rate of 0.13 fluid ounce (6.55 grams) per injection in holes 6 to 9 inches deep. (See table 2). All treatments were made in duplicate.

The distance the gas would have to spread through the soil could have been minimized by staggering the holes. This was not done because it was thought best to study the results at the maximum distance encountered with an 18-inch spacing. Table 2 gives the effectiveness of these materials.

Surface Application of Emulsion.—Carbon disulfide emulsion was the only material mixed with water. The stock emulsion used contained 65 per cent of carbon disulfide.[6] The stock emulsion was diluted 1 to 300, and 5 gallons of this dilute mixture per square yard was applied with a sprinkling can. Two plots were treated with this material, and in order to secure an even application of the emulsion the plots were staked out in yard squares. After treating this area the edges of the plots were well wetted with the emulsion.

COMPARATIVE EFFECTIVENESS OF THE CHEMICALS USED

A population study of the plots was made before treating them to determine the effectiveness of the various materials used. Two cylindrical samples 6 inches in diameter and 9 inches deep were taken from each plot, and a complete count of the centipedes in each sample was made. The figure used for initial population was the average of the

[6] This emulsion is a product of Wheeler, Reynolds, and Stauffer Company, San Francisco.

count in the two samples. This gave a rather complete picture of the distribution of the centipedes through the experimental area.

From time to time after the treatment of the plots, examinations were made for centipedes. These showed that carbon disulfide, carbon disulfide emulsion, carbon tetrachloride, chloropicrin, and calcium cyanide killed rapidly. At least in the case of the first three mentioned, almost all killing appeared to take place in the first 24 hours. The lethal effects of naphthalene and paradichlorobenzene were drawn out for a rather long period. The killing action of paradichlorobenzene lasted until apparently all the centipedes were killed, but the effect of naphthalene wore off before the centipedes were eradicated.

Approximately 2½ months after treating the plots a second population study was made. This should have allowed enough time for all the materials used to have exerted their full killing power. When the final count was made the population was so low on some of the treated plots that it seemed advisable to take larger samples than had been used in the first counts. Accordingly, 10 shovelfuls of soil were examined from each plot. The formula used in calculating the effectiveness of the treatment was designed to correct for the difference in volume between the samples of the first and second counts.

Since all of the chemicals except carbon disulfide emulsion were applied under favorable conditions, they could not be considered effective unless they resulted in nearly a 100 per cent kill. The conditions necessary for good results with carbon disulfide emulsion are discussed on page 15.

Table 2 shows the effectiveness of the various materials used. The effectiveness of the chemicals is expressed as a percentage of the initial population killed; the following formula[7] was used in calculating these results:

$$\text{Effectiveness} = \frac{(\text{initial population} - \text{corrected final population}) \times 100}{\text{initial population}}$$

The effectiveness of the individual treatment, and also the average of duplicate treatments are shown in the table. Although most of the plots receiving the same applications check rather closely with one another, several exceptions to this may be noted. In plot 18 (naphthalene 1,200

[7] The corrected final population of each plot was found by multiplying the actual final population by a factor which included two corrections: (1) the average ratio of initial and final populations of the five check plots, and (2) the ratio of the volume of the earth used in the initial and final population counts of the test plots. In this way the actual increase in population during the long interval (2½ months) between counts and the unavoidable change in method of counting were both allowed for, so that all counts are reduced to the same basis.

TABLE 2

EFFECTIVENESS OF VARIOUS CHEMICAL TREATMENTS IN KILLING THE GARDEN CENTIPEDE

Chemical	Method of application	Rate of application		Depth of application	Plot No.	Effectiveness expressed as per cent of initial count	
		Per hole	Per acre			Of each plot	Average of duplicate plots
		fluid ounces		*inches*			
Carbon disulfide	Injected into the soil 18 inches apart each way	1.92	290 gal.	6	1	100	100
					27	99	
				9	13	100	100
					39	100	
		0.96	145 gal.	6	11	100	100
					19	100	
Carbon tetrachloride	Injected into the soil 18 inches apart each way	1.92	290 gal.	9	7	52	59
					29	66	
Chloropicrin	Injected into the soil 18 inches apart each way	0.13	280 lbs.	6–9	5	53	54
					32	54	
Carbon disulfide emulsion	Diluted 1 to 300; 5 gal. applied to the square yard	.....	.....	Applied to soil surface	10	41	26
					31	11	
Calcium cyanide	Sown in furrows	.....	300 lbs.	6	2	52	54
					26	56	
			600 lbs.	6	15	73	65
					25	57	
			900 lbs.	6	16	70	80
					36	89	
Equal parts of hydrated lime and sulfur	Broadcast and spaded under	.....	1,200 lbs.	.....	3	33	7
					20	—20*	
Naphthalene	Broadcast and spaded under	.....	1,200 lbs.	.....	18	93	79
					37	65	
Lead arsenate	Broadcast and spaded under	.....	300 lbs.	.....	4	—20*	0
					21	20	
Equal parts of potassium xanthate and sulfur	Sown in furrows	.....	1,200 lbs.	6	6	53	9
					23	—35*	
			2,400 lbs.	6	14	—130*	—62*
					38	5	
Paradichlorobenzene	Sown in furrows	.....	300 lbs.	6	28	86	80
					33	74	
			600 lbs.	6	19	100	100
					24	100	
			900 lbs.	6	17	100	100
					35	100	

* The minus percentages, indicating a greater relative increase of the centipede in these plots than in the check plots, are probably due to an underestimation of the initial population, as explained on page 12.

pounds per acre) the 93 per cent kill is undoubtedly high. The only explanation that can be offered is that the original population in this plot was low, and therefore, in the population studies before or after treatment a few centipedes observed one way or the other would tend to alter the results greatly. The same seems to be true of plot 6 (potassium xanthate + sulfur, 1,200 pounds), for this material is unquestionably ineffective against the garden centipede. The minus percentage obtained in plot 14 (potassium xanthate + sulfur, 2,400 pounds per acre) is probably due to an underestimation of the first population count, for several checks on the second count showed it to be correct. The other minus percentages are perhaps also the result of exceptionally low first counts, together with experimental error.

From table 2 it is seen that the two chemicals producing near eradication are paradichlorobenzene and carbon disulfide. Of these paradichlorobenzene was preferable when cost was taken into consideration. None of the other chemicals can be considered effective under the conditions of the experiment. Unless eradication or near eradication is accomplished, chemical treatment against the garden centipede is not justified. The one exception to this is carbon disulfide emulsion, and this will shortly be considered.

Paradichlorobenzene.—Paradichlorobenzene, when used at the rate of 600 or 900 pounds per acre, gave, as far as could be ascertained, complete eradication of the centipede. Preliminary results had indicated that this chemical is not effective unless it is applied in the summer when the soil temperature is high, and unless thorough and even distribution is obtained. Packing the soil after it is applied is advisable because this prevents the evolving gas from escaping too easily from the soil. While this material is very effective against the garden centipede when applied under proper conditions, it has several disadvantages: (1) It should not be used where there is vegetation, for it is almost certain to be injurious. (2) The fumigant is rather slowly dissipated, and after its application several months should pass before treated ground is planted. (3) It should only be applied during the summer if satisfactory results are to be expected.

Carbon Disulfide.—Carbon disulfide gave good results when used at the rate of 145 and 290 gallons per acre. However, when 145 gallons per acre are used, control can only be expected under the most favorable conditions. This is based upon rather extensive work other than that carried on in the work here described. As with paradichlorobenzene, best results can be expected in the summer when the soil is very warm. However, this material has a greater range of effectiveness than paradi-

chlorobenzene, and when used at the higher rate (290 gallons per acre) good results have been obtained during the spring and fall. This material kills with great rapidity, and in one plot examined 18 hours after treatment all animal life appeared to have been killed, including the garden centipede, true centipedes, sowbugs, earthworms, and millipeds.

Several precautions should be used when treating soil with this material. After the material is applied the holes should be tamped tightly shut, and it is well to firm the whole soil surface by wetting or rolling to prevent the escape of the gas. At time of application the soil should not be too wet, as very wet soil apparently cuts down the effectiveness of the chemical by preventing the penetration of gas through it. In one greenhouse where a rather extensive area was treated with this chemical, very poor control was obtained, and for no apparent reason other than that the soil was very wet.

Carbon disulfide is very inflammable and explosive when mixed with air. It should be kept away from all flame and from electric sparks, and smoking should be prohibited. This material is also injurious to growing plants, and, therefore, its use is mostly limited to areas free from vegetation. However, it dissipates very rapidly, and planting can take place in a week after its application without injury. In fact, in some cases it has been reported that growth has been stimulated by it, probably owing to the partial sterilization of the soil.

Carbon Disulfide Emulsion.—While carbon disulfide emulsion[8] gave unsatisfactory results when used in the experimental area, it has been tried in greenhouses with some success. This material has an advantage over paradichlorobenzene and carbon disulfide in that it can be used where vegetation is growing. When diluted 1 to 300, and applied at the rate of 5 gallons to the square yard, it has given fair to good control. At this rate of application, the chemical is not injurious to many plants, although some, such as asters, have been severely injured. This material is not effective unless the centipedes are near the soil surface, and the soil is wet, loose, and porous so that the liquid can penetrate it readily. Wetting the soil has a tendency to bring the centipedes close to the soil surface. In greenhouses where this material has been applied under optimum conditions, no living centipedes could be found the day after the treatments, although many dead ones were evident in every shovelful of soil examined. The diluted emulsion should be kept well agitated and applied soon after mixing to prevent the escape of the carbon disulfide

[8] If carbon disulfide emulsion is mixed indoors, the room should be well ventilated. Further, the container in which it is mixed should be drained and washed. Otherwise, upon standing, there is some danger that enough carbon disulfide may escape from any remaining emulsion to form an explosive mixture.

gas, which is slowly given off. In experimental work, where rather large areas were to be treated, the dilute emulsion was made up in a 50-gallon barrel, and applied to the infested ground with a sprinkling can. It is very probable that any centipedes fairly deep in the soil will not be affected by the emulsion, and these, with others that are likely to migrate into the beds, will set up new infestations, making it necessary to treat the beds from time to time. This is particularly true where plants remain in the soil for rather long periods. However, under favorable conditions a profitable crop of short-lived plants such as snapdragons, could probably be obtained with one or two applications of the emulsion.

CONCLUSIONS

From the work carried out it has been determined that paradichlorobenzene, carbon disulfide, and carbon disulfide emulsion are very effective when used against the garden centipede. The rate at which these chemicals must be used in order to be effective will undoubtedly prohibit their use in the control of the centipede under field conditions, except in special cases. However, there are many greenhouses in which the centipede is proving to be a serious pest. In places it has made the production of certain plants uneconomical. In such places chemical treatment of the soil might readily relieve this situation. The only other alternative is to install raised benches where the plants to be grown can be propagated in this type of bed.

SUMMARY

In order to study the effect of chemical treatment in combatting the garden centitpede, *Scutigerella immaculata* (Newport), experimental plots were isolated by keeping them continuously surrounded by water.

Chemicals experimented with were paradichlorobenzene, calcium cyanide, naphthalene, lead arsenate, potassium xanthate mixed with equal parts of sulfur, hydrate of lime mixed with equal parts of sulfur, carbon tetrachloride, carbon disulfide, carbon disulfide emulsion, and chloropicrin.

The experimental plots were treated during the summer when the soil temperature was high, and this is believed to have allowed the chemicals to exert their fullest lethal power.

During the course of the experiment soil temperatures were recorded for 3 and 10-inch soil levels, a Bristol's recording thermometer being used for this purpose.

In order to determine the effectiveness of the various chemicals, population studies were made before and after treating the plots, and

effectiveness calculated by a formula to correct for a change in the method of counting population and for normal increase in numbers.

Examinations after treating the plots showed that carbon disulfide, carbon disulfide emulsion, carbon tetrachloride, chloropicrin, and calcium cyanide killed rapidly, with the first three, at least, exerting their fullest killing power during the first 24 hours.

Paradichlorobenzene and naphthalene appeared to kill rather slowly, with the lethal action of paradichlorobenzene lasting until apparently all the centipedes are killed.

Of the chemicals experimented with, the only ones that showed promise in the control of the garden centipede were paradichlorobenzene, carbon disulfide, and carbon disulfide emulsion, when the rate of application was heavy enough.

While carbon disulfide emulsion did not give good results when used in the experimental plots, it has given satisfactory control under certain greenhouse conditions. It is effective only when the centipedes are concentrated near the surface of the soil, and the soil is loose, porous, and moist so that the emulsion penetrates it readily.

Paradichlorobenzene proved effective when used at the rate of 600 and 900 pounds per acre. This chemical should be applied only in the summer when the soil temperature is high, if effective control is to be obtained.

Carbon disulfide proved effective when used at the rate of 145 and 290 gallons per acre. The effectiveness of the 145-gallon treatment is believed to be due to the fact that it was applied under most favorable conditions.

Paradichlorobenzene and carbon disulfide are both injurious to vegetation and, therefore, their use is mostly limited to areas free of growing plants.

Carbon disulfide emulsion has an advantage over the above-mentioned chemicals in that it can be applied to many different kinds of plants without causing injury to most of them.

Because of cost, chemical control of the centipede under field conditions will probably prove uneconomical in most cases, although on small areas and in greenhouses such treatment may be profitable.

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